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PRELIMINARY REPORT

ON

KEARNEY VINEYARD EXPERIMENTAL DRAIN

FRESNO COUNTY, CALIFORNIA

BY

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(Based on work done under a co-operative agreement between the Office of Public Roads and Rural Engineering, U. S. Department of Agriculture, and the University of California Agricultural Experiment Station.)

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INTRODUCTION

The need for drainage in many of the irrigated sections of the San Joaquin Valley was noted and reported upon by the late Dr. E. W. Hilgard [1] as early as 1886. In 1902 C. G. Elliott [2] surveyed and reported upon the drainage of about twenty-five square miles of territory in Fresno County and in a subsequent report [3] recommended drainage for the city of Fresno. In 1907 W. W. Mackie[4] reported on experiments in drainage that were carried on by the Bureau of Soils, U. S. Department of Agriculture. In 1909 Dr. Samuel Fortier and V. M. Cone[5] reported on experimental drainage in the Fresno section and made preliminary recommendations for the drainage of about 200,000 acres.

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[1] Reports of California Experiment Station, 1886 to 1896.

[2] Circular 50, Office of Experiment Stations, U. S. Department of Agriculture.

[3] Circular 57, Office of Experiment Stations, U. S. Department of Agriculture.

[4] Bulletin 42, Bureau of Soils, U. S. Department of Agriculture.

[5] Bulletin 217, Office of Experiment Stations, U. S. Department of Agriculture.

With the idea of making further experiments on a larger area than had been previously used and of carrying these experiments to a more definite conclusion than those of former cases, the Kearney Vineyard experimental drain was installed under the co-operative direction of the University of California Agricultural Experiment Station and the Office of Experiment Stations, U. S. Department of Agriculture.

Although this tract has not yet been brought to an entirely satisfactory state of productiveness, the results have been such as to give indication of the entire success of the project. This preliminary report is intended to show only what progress has been made during the first three years.

LOCATION

The drained tract, which consists of a quarter section (S.E. ¼ sec. 6, T. 14 S., R. 19 E. M.D.M.) of the Kearney Vineyard property, lies one mile northwest of Kearney Park and about eight miles west of Fresno, along White's Bridge Road between Fillmore and Monroe Avenues.

HISTORY OF THE TRACT

About 1890 this tract, which is a part of what was then known as the Fruit Vale Estate, was brought into productiveness as a vineyard by Mr. Theodore Kearney. It is said to have been as valuable as any part of the estate during the first years. Later, seepage and alkali began to appear and the vineyard deteriorated rapidly until all but a small portion was removed. The tract was then planted to alfalfa, which gave satisfactory yields for a few years, but the water table continued to rise until the alfalfa became unprofitable and the entire tract was used for grain up to the time that the reclamation work was started. In 1912 the entire quarter section produced only about 30 tons of barley hay and this largely from the sandy ridge in the northwest corner of the tract. In 1913 the tract was uncultivated, some parts being entirely barren of vegetation, while a rank growth of alkali weeds and foxtail covered most of it.

PRELIMINARY SURVEY

During the summer of 1913 detailed topographical, soil and alkali surveys were made of the area. The topography is somewhat irregular, the general slope is about 2¼ feet from north to south. A sandy ridge runs through the northwest part of the field, with a deep depression just to the west. A shallower depression lies just east of the ridge,

and a broad, flat area extends from this through the middle of the field. With the exception of the one deep depression, the local differences in elevation are less than two feet.

The soil is mapped by the Bureau of Soils[6] as "Fresno sandy loam," whereas the more detailed survey mentioned separated it into the sandy loam and fine sandy loam types, each occupying irregular shaped areas over the tract. Practically the entire area is underlain by hardpan at depths ranging from a few inches to several feet, of a thickness ranging from a few inches to four feet. Sometimes several layers of hardpan were encountered within a six-foot soil column. Hardpan conditions varied considerably within short distances, and

Fig. 1.—View showing character of vegetation in 1913.

as was found later, offered little resistance to the downward movement of water.

The detailed survey showed that the alkali varied in the surface foot from less than .2 per cent over most of the tract to 3.0 per cent over small areas. It was found that the principal salts were sodium chloride and sodium carbonate, with a predominance of the former. Observations taken during 1912 and the early part of 1913 showed that at no time during the year was the water table more than seven and one-half feet below the surface, and during June it stood within two feet of the surface. During the entire growing season the water was less than six feet from the surface, and for four and one-half months was less than four feet below the surface.

[6] Field Operations of Bureau of Soils, 1912—Fresno Area.

PLAN OF DRAINAGE

The system of drainage installed during November and December, 1913, consists of a main drain, beginning near the center of the north line of the tract, running south to within about 600 feet of the south line, thence southeastward 750 feet and thence east to a sump at the southeast corner. The main drain has a fall of 1 in 1000 and an

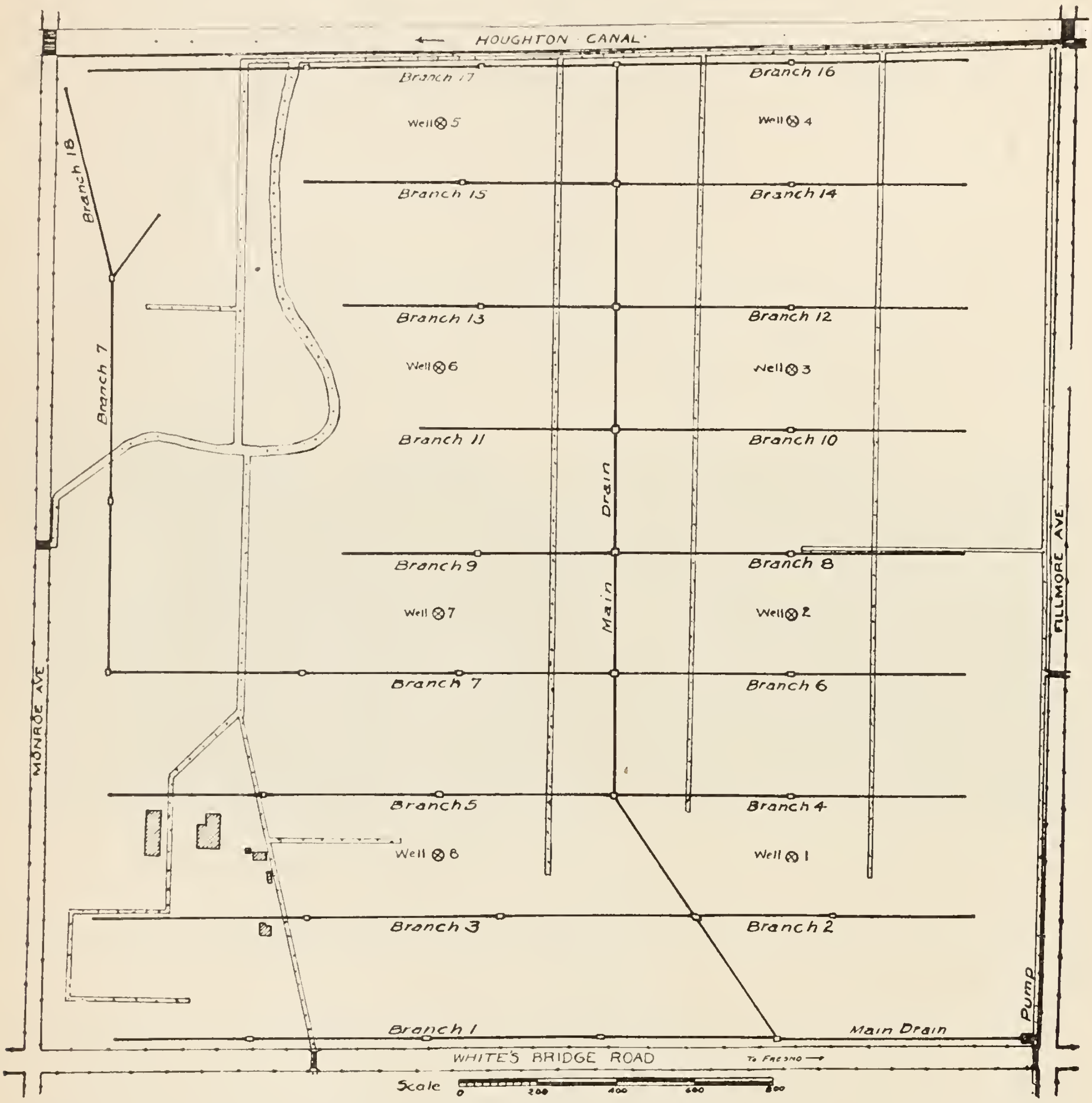

Fig. 2.—Sketch showing location of drains and test wells on Kearney Vineyard Experiment Drain.

average depth of about seven feet. As originally constructed, the upper 300 feet were 6-inch tile, followed by 1588 feet of 8-inch tile and 1400 feet of 12-inch tile. The lateral system, consisting of eight parallel laterals on the east and nine on the west side of the main, is composed of 6-inch tile at an average depth of five and three-quarters feet. The laterals are 315 feet apart, those on the east of the main

drain being 900 feet long, while those on the west, due to the topography, vary from 500 feet to 1700 feet long. Branch No. 7 differs from the others in that it extends north along the west line in order to reach the deep depression at the northwest corner of the tract. The tile, with

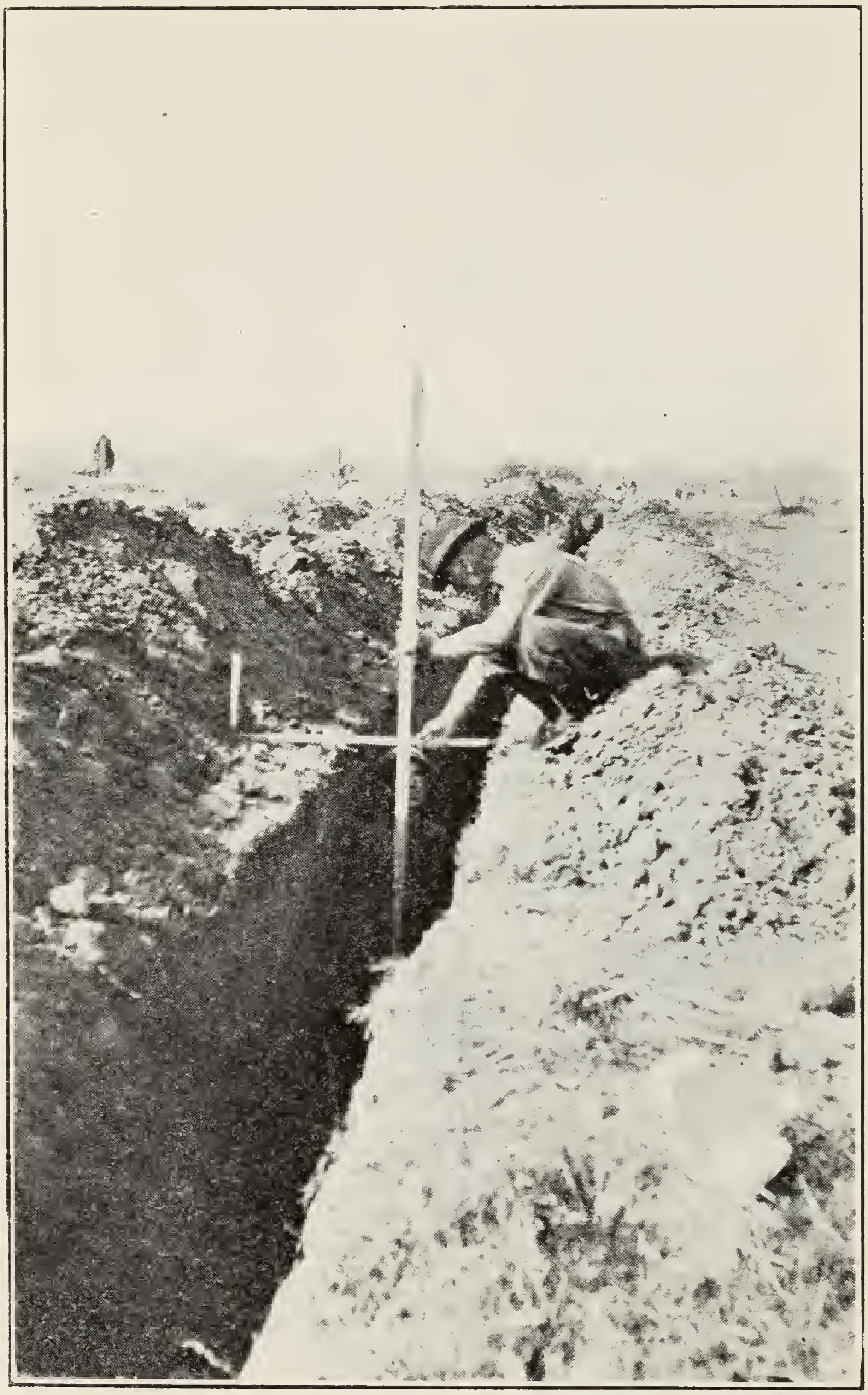

Fig. 3.—Drainage system under construction. Note depth of trench.

the exception of 640 feet of 12-inch sewer pipe, was ordinary hard-burned clay drain tile in two-foot lengths. Each piece was laid to grade with abutting joints. No protection was provided at the joints for keeping out silt.

Concrete silt wells were placed along the main drain at the points where the laterals enter, and at distances of not more than 500 feet apart on the laterals. These silt wells vary in size from 4 × 4 feet to 2½ × 4 feet and have an average depth of about eight feet. The bottom is in each case one and one-half feet below the tile grade. The sump at the southeast corner of the tract consists of a reinforced concrete pit five and one-half feet square and sixteen feet deep, with the inlet tile four feet from the bottom. The water was originally pumped from this sump with a 3½-inch vertical centrifugal pump operated by a 5 H.P. direct-connected motor. The irrigation laterals were lined with concrete at all points where they crossed the tile lines to prevent excessive seepage into the new trenches. Fig. 2 shows the plan of the system.

CONSTRUCTION AND COST IN 1913

Construction was done by contract, the contractor receiving a commission of 10 per cent on the labor and materials, exclusive of tile and pumping equipment. This arrangement, however, was not strictly adhered to as both labor and materials were furnished without commission. The trenches were all dug by hand and at no place except in the vicinity of the sump was any water or serious caving encountered.

The system consists of 21,842 feet of drain varying in size from 6-inch to 12-inch tile, including 640 feet of 12-inch sewer pipe used for the lower end of the main line because of the deep cut here. The tile cost 7¼ cents per foot for 6-inch, 13 cents per foot for 8-inch, and 26 cents per foot for 12-inch, totaling $2018.55 or an average of $0.0924 per foot, f.o.b. Kearney Park. Distributing the tile, digging trenches, laying, backfilling, tools and repairs amounted to $4352.38, divided as follows:

Digging and laying	$2935.42
Backfilling	293.99
Supplies and blacksmithing	821.17
Commission	301.80
	$4352.38

The structures, including the material and work on the silt wells, irrigation crossings and sump, amounted to $2066.24, of which $1015.34 was for materials and $164.45 for commission. This was divided approximately as follows:

Sump	$500.00
Thirty-four silt wells	1258.00
Twenty-eight crossings	308.24

The pump equipment cost $561.35, divided as follows:

Transformers	$160.00
Pump, motor, etc.	401.35

A summary of the cost of the drainage plant as installed in December, 1913, on a basis of 151 acres of arable land, is given in the following table:

Item—	Total	Per acre
Tile	$2018.55	$13.37
Digging and laying	2750.67	18.23
Distributing tile	184.75	1.22
Backfilling	293.99	1.94
Supplies and blacksmithing	821.17	5.44
Sump	460.00	3.05
Silt wells	1163.55	7.70
Crossings	278.24	1.84
Pump equipment	561.35	3.71
Commission	466.25	3.09
	$8998.52	$59.59

The cost for installing the tile was:

Item—	Total	Cost per foot of drain
Tile	$2018.55	$.0924
Digging and laying	2750.67	.1259
Distributing	184.75	.0085
Backfilling	293.99	.0135
Supplies and blacksmithing	821.17	.0376
	$6370.93	$.2917

Immediately after the completion of the drainage system, steps were taken to prepare the land for flooding. This work consisted of repairing the irrigation system and rechecking the field, both of which had become neglected through disuse. The repairs to the irrigation system cost $235.17, or $1.56 per acre, and the leveling cost $725.56, or $4.80 per acre, making a total expenditure at the time flooding was commenced in February, 1914, of $9959.25, or $65.95 per acre.

OPERATIONS AND EXPENSES DURING 1914

The first actual work of removing the alkali and lowering the water table was begun by starting the pump on February 23, 1914. At the same time water was turned into the field for flooding. The flooding continued intermittently until April 22, at which time all of the tract except about forty acres along the west line had been flooded for at least a week, to a depth of six to twelve inches.

Shortly after the flooding began, it became apparent that the pumping equipment was too small to handle the water, and an auxiliary gasoline outfit was installed at one of the silt wells at about the middle of the field. The auxiliary pump was kept in operation until June 30 and the discharge was used for flooding. During the operations of this pump it is estimated that 46,000,000 gallons were pumped by it, practically all of which was returned to the land and no account

Fig. 4.—The tract was flooded in order to wash the alkali down.

is taken of this in subsequent estimates on discharge. It is now thought that this outfit did not assist materially in lowering the water table, as nearly all of the water which did not evaporate was returned to the drains and eventually handled by the main pump.

During June, the east eighty acres of the tract were irrigated, plowed and planted to Egyptian corn. The stand of corn was rather unsatisfactory, probably not more than paying for its harvesting. It did, however, give some indication as to the progress of the reclamation.

At the end of the 1914 season several instances of faulty design were apparent and changes were made in the system to correct these.

The 3½-inch vertical pump and 5 H.P. vertical motor were found to be both too small and of poor design for this work, and they were replaced by a 5-inch horizontal centrifugal pump and 7½ H.P. direct connected motor. This new equipment included changes in the pump house and a device for controlling the discharge. It was also found that a considerable portion of the water entering the main line of the

Fig. 5.—The corn grown in 1914 showed many bare spots.

tile system came from the laterals near the northern end of the field, evidently seepage directly from the Houghton Canal; from observations made while the auxiliary pump was in operation, it was found that portions of the main line were too small and probably would not have handled satisfactorily the entire drainage even if the pump equipment had been larger. As a consequence, all of the 8-inch tile was replaced by 12-inch tile and all of the 6-inch tile in the main line by 10-inch tile. The total expenses for the year were as follows:

Item—	Total	Per acre
New pump equipment	$377.10	$2.49
Tile replaced	373.76	2.47
Labor replacing tile	686.50	4.55
For flooding	218.06	1.44
Pumping (both pumps)	684.02	4.54
Auxiliary pump	148.84	0.98
Plowing (Bermuda grass control)	296.70	1.97
Maintenance of tile line	28.00	0.18
	$2812.98	$18.63

Total for the project at the beginning of 1915 season, $12,772.23, or $84.58 per acre.

Aside from the changes which have been mentioned, it now became apparent that considerable of the first cost might have been saved by a more economical design of the structures. The concrete linings in the irrigation laterals were found to be of no real service, and could have been omitted entirely. Equal efficiency could no doubt have been obtained by omitting all of the silt wells except those on the main line and one on lateral No. 7, and by using redwood instead of concrete in their construction.

During the construction of the sump, adverse subsoil conditions were encountered which no doubt increased the cost of the sump by several hundred dollars over what it would have cost if located elsewhere. It is probably also true, although as yet not conclusively proven, that equal efficiency could have been obtained by spacing the laterals about 400 feet apart, instead of 315 feet, thus eliminating one on each side of the main drain. This last change could certainly have been made had the laterals been placed eight inches to one foot deeper. These duplicate and apparently unnecessary expenditures were caused, in the first instance, because it was found that the measured drainage discharge for this tract is more than double that usually found in irrigated sections, and in the second instance, by the experimental nature of the undertaking.

OPERATIONS AND EXPENSES DURING 1915

Immediately after flooding operations were discontinued in 1914, a rank growth of Bermuda grass sprang up over the tract, replacing the growth of alkali weeds which were so abundant in 1913. It is probable that some of the seed of this grass was brought to the field by the water used in flooding and also there seems to be little doubt but that much of it was dormant in the soil and started to grow as

soon as growing conditions were improved. It now became apparent that before successful crops of alfalfa could be grown the Bermuda grass must be eradicated and, consequently, after the second flooding, which took place in April, 1915, and covered practically the same area as was flooded the previous year, the entire season was spent in attempting to control this grass. The tract was plowed to a shallow depth several times, so as to expose the roots to the hot sun. The loosened grass was raked together and burned. The end of the season showed a very marked reduction in the amount of Bermuda grass present. During the year 1915 the following expenses were incurred.

Item—	Total	Per acre
Maintenance and repairs to drain and pump	$70.64	$0.47
Repairs to irrigation system	95.50	0.63
Pumping costs (power, etc.)	278.15	1.90
Flooding	149.38	0.99
Control of Bermuda grass	1843.48	12.21
	$2447.15	$16.20
Total for project, January, 1916	$15,219.38	$100.78

The expenditures shown in this report do not include planting or harvesting the corn in 1914, nor the hay in 1916, nor water taxes for three years; neither do they include rebate on tile replaced, main pump and motor replaced or the auxiliary pump.

PUMPING AND FLOODING

Beginning February 23, 1914, and continuing until May 1, the tract was being flooded. Within a week after flooding began, ten acres or more were under water, but the first pump which was installed proved too small and the ground water rose rapidly during the flooding. The flooding was then discontinued until after the auxiliary pump was installed. During the flooding as much land was kept under water as possible, so that the alkali would be carried downward rather than laterally. As much as forty acres were under water at one time. No estimates were obtained showing the amount of water used in flooding, except that the area flooded was kept under water from six inches to twelve inches deep for a period of at least one week. Measurements taken of the pump discharge show that there were approximately 97,580,000 gallons or 300 acre-feet removed from the tract during the year. This is sufficient water to cover the entire 160 acres 1.88 feet deep. This does not include any discharge from the auxiliary pump.

Due to the flooding and the lack of proper pumping equipment, the ground water remained high during the season. In 1915 with the larger equipment in place, the flooding was resumed in March and continued throughout April, covering about the same ground as before and for about the same period. The water used in flooding was not measured.

The pump discharge for each week during the seasons of 1915 and 1916 is shown in the following table.

1915 Week ending—	1915 Gallons	1916 Week ending—	1916 Gallons
Mar. 27	5,480,000	Mar. 25	†
April 3	6,790,000	April 1	3,018,000
" 10	8,780,000	" 8	†
" 17	10,240,000	" 15	7,616,000
" 24	9,500,000*	" 23	6,731,000
May 1	9,500,000*	" 30	9,900,000
" 8	9,700,000	May 7	8,904,000
" 15	7,620,000	" 14	7,968,000
" 22	8,290,000	" 21	7,907,000
" 29	7,810,000	" 28	7,308,000
June 5	8,330,000	June 4	6,552,000
" 12	7,350,000	" 11	6,216,000
" 19	6,220,000	" 18	6,266,000
" 26	5,360,000	" 25	7,140,000
July 3	4,710,000	July 2	6,200,000*
" 10	4,870,000	" 9	6,000,000*
" 17	6,300,000	" 16	5,800,000*
" 24	5,390,000	" 23	5,662,000
" 31	4,440,000	" 30	5,538,000
Aug. 7	3,500,000	Aug. 6	5,999,000
" 14	2,630,000	" 13	5,309,000
" 21	1,630,000	" 20	6,449,000
" 28	420,000	" 27	8,803,000
Sept. 4	850,000	Sept. 3	6,443,000
		" 10	5,796,000
		" 17	5,040,000
		" 24	3,393,000
		Oct. 1	1,026,000
Total	145,710,000	Total	162,984,000

* Estimated.
† Pump not running.
1915 discharge equals 447.7 acre-feet, or 2.79 acre-feet over 160 acres.
1916 discharge equals 500.1 acre-feet, or 3.12 acre-feet over 160 acres.

During 1915 the pump was in actual operation 3534 hours out of the total of 3648 hours, or 96.8 per cent of the time between March 22 and August 20, discharging 144,440,000 gallons, or 1.52 cubic feet

per second. During 1916 the pump was in actual operation 3921 hours out of a total of 4056 hours, or 96.6 per cent of the time between April 10 and September 25, discharging 159,966,000 gallons, or 1.51 cubic feet per second.

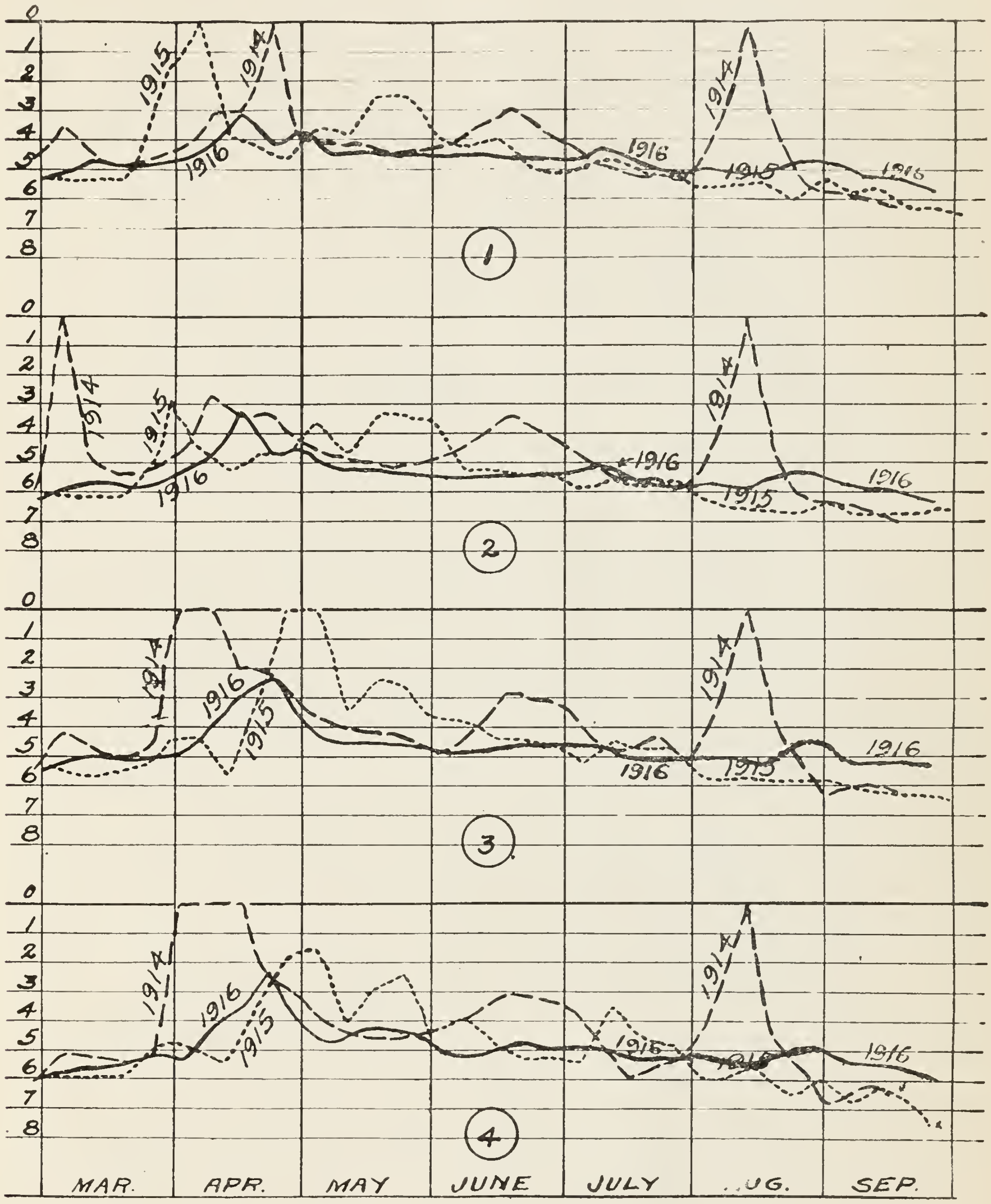

Fig. 6.—Curves showing ground water table on Kearney Vineyard Experiment Drain.

In 1915 the maximum weekly discharge occurred during the week of April 17, when 10,240,000 gallons were pumped during 160 hours, or an equivalent of 2.38 cubic feet per second. During 1916 the maximum discharge occurred during the week ending April 30, when there

were 9,900,000 gallons pumped during 165 hours, or 2.23 cubic feet per second.

The increased discharge in 1916 is due to the pumping season

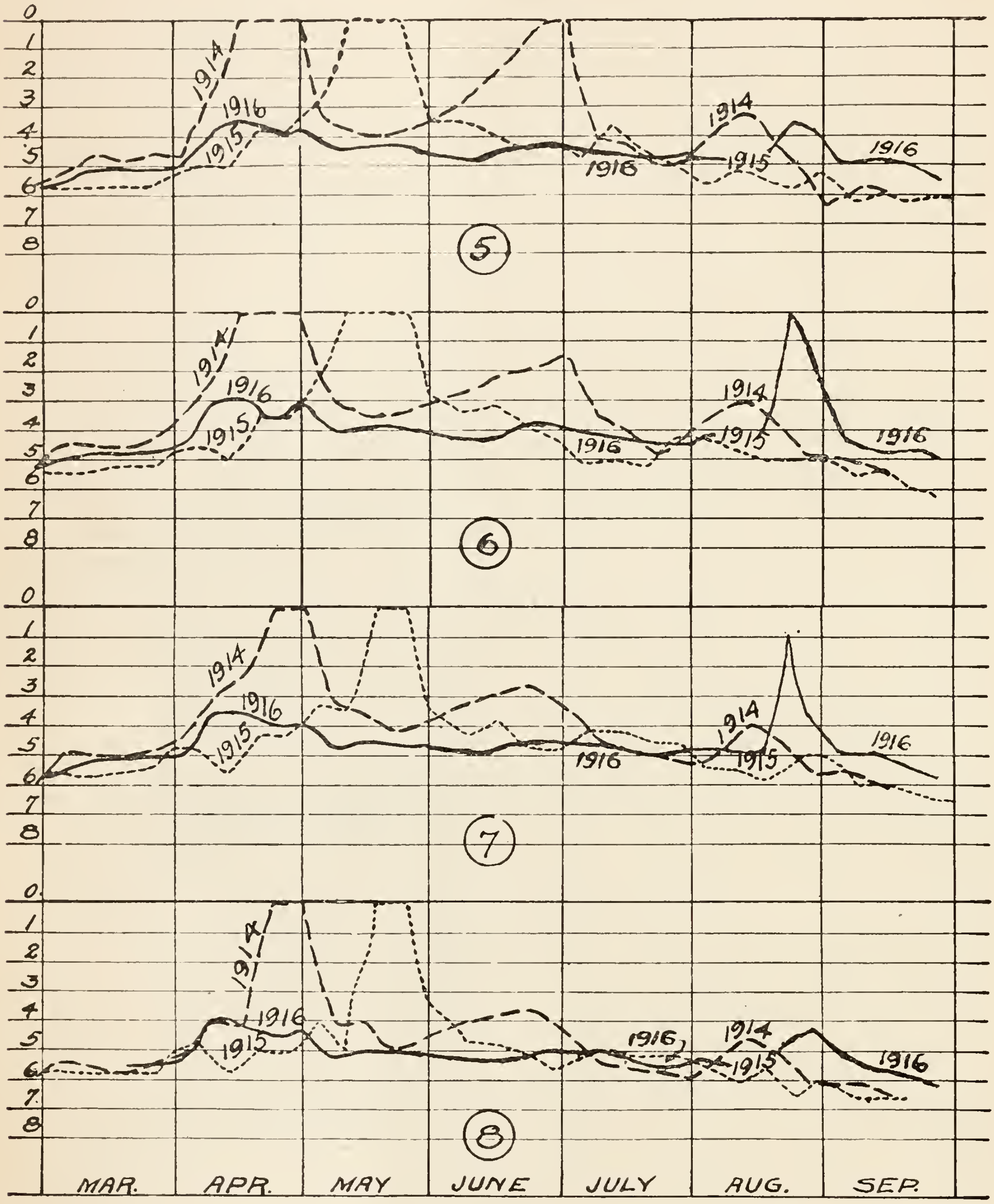

Fig. 7.—Curves showing ground water table on Kearney Vineyard Experiment Drain.

being lengthened by a late irrigation, in order to facilitate preparing the land for the 1917 crop.

Figures 6 and 7 show the depth to water from March to September inclusive for 1914, 1915, and 1916. These observations were made by weekly reading on test wells located midway between laterals and

450 feet from the main drain. Numbers 1 to 4 are located east of the main line and numbers 5 to 8 west of the main line. (See Fig. 2.)

The irregularities in the curves show the effect of flooding in the vicinity of the test well. The effect of the irrigation which the grain received in April, 1916, is shown quite plainly in all of the wells by the rise in the water table.

Taking May 22, 1916, as a representative date, the average of the eight wells on this tract shows the water table to be 4.8 feet below the surface, while on the same date, as shown by an average of eighteen wells, the water stood one foot higher on other parts of the Kearney Vineyard property. On the same date the average depth to water was 2.6 feet in three wells on the tract immediately south of the drained area.

REMOVAL OF ALKALI

The soil and alkali survey made in the summer of 1913 showed, as has been stated, that the surface foot, over a considerable portion of the tract, contained less than .20 per cent of combined salts, although there were areas where there was 3.0 per cent or over. The most alkaline portions were in the depressions, which have been described as being on either side of the ridge near the northwest corner of the tract. An area containing as high as 1.0 per cent was found covering about the center third of the east eighty acres.

In the fall of 1913 a series of analyses were made of soil samples taken from holes fifty feet apart on two parallel lines fifty feet apart running from the southeast to the northwest corner of the tract. The results of these analyses were compared with analyses made from soil samples taken from the same places in July, 1914, and July, 1915. In 1913 and 1914, samples were taken of each foot of soil from the surface to hardpan. During 1915 samples were taken for each foot from the surface to six feet.

Local variations in the alkali content of the soil make individual tests rather misleading and in order to reach any conclusions, all the tests in both lines were taken collectively. The following table gives the results of this method of handling the data.

SODIUM SALTS IN SURFACE FOOT

Year—	No. of tests	Per cent NaCl	Per cent Na_2CO_3	Total
1913	122	.0972	.0401	.1373
1914	119	.0276	.0406	.0682
1915	138	.0208	.0338	.0546

1914 decrease in NaCl, 71.6 per cent; increase in Na_2CO_3, 1.2 per cent; decrease in total alkali, 50.3 per cent.

1915 decrease in NaCl, 78.6 per cent; decrease in Na_2CO_3, 15.7 per cent; decrease in total alkali, 60.3 per cent.

Fig. 8 shows the same results graphically. It will be noted from the above table that of the total, .1373 per cent of salt in the surface foot in 1913, 70.8 per cent was NaCl, or common salt, and 29.2 per cent Na_2CO_3, or black alkali. In 1914 there was a decrease of 71.6 per cent in the NaCl and an increase of 1.2 per cent in the Na_2CO_3, making a total decrease of 50.3 per cent. In 1915 the decrease in NaCl was 78.6 per cent of the amount present in 1913 and there was also a decrease of 15.7 per cent in the Na_2CO_3 for the same period, making a total decrease in two years of 60.3 per cent. The proportion of the two salts making up the remaining total of .0546 per cent of the soil had changed from a predominance of NaCl to a predominance of Na_2CO_3.

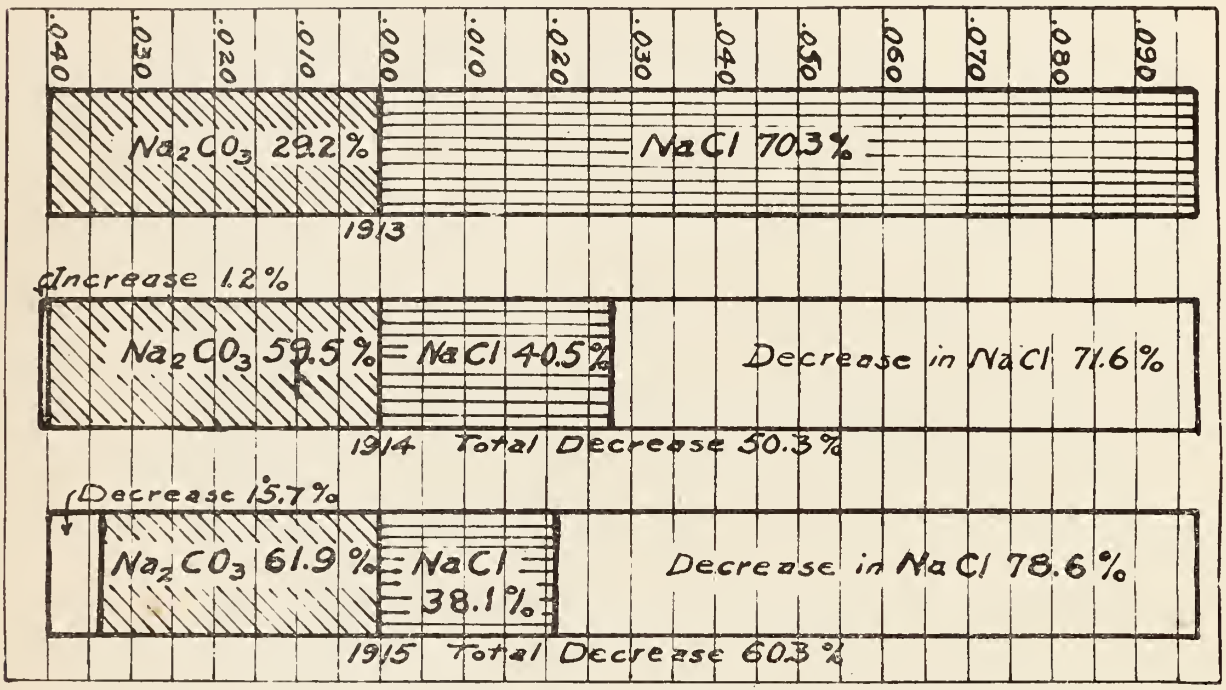

Fig. 8.—Sodium salts in surface foot. Percentage of decrease and amount and percentage remaining after one and two years' drainage.

The following table shows the distribution of sodium salts through soil column in 1915.

Depth—	No. of tests	Per cent NaCl	Per cent Na_2CO_3	Total
First foot	138	.0208	.0338	.0546
Second foot	138	.0161	.0263	.0424
Third foot	139	.0145	.0222	.0367
Fourth foot	138	.0125	.0196	.0321
Fifth foot	139	.0104	.0174	.0278
Sixth foot	137	.0093	.0163	.0256
Agerage	138	.0139	.0226	.0365

Fig. 9 shows graphically the same results as found in the above table. This diagram shows that both salts decrease quite regularly with the depth. Unfortunately, we have no data for making a similar diagram for 1913 and 1914, consequently it is not known whether the salts that have been removed from the surface foot have been redis-

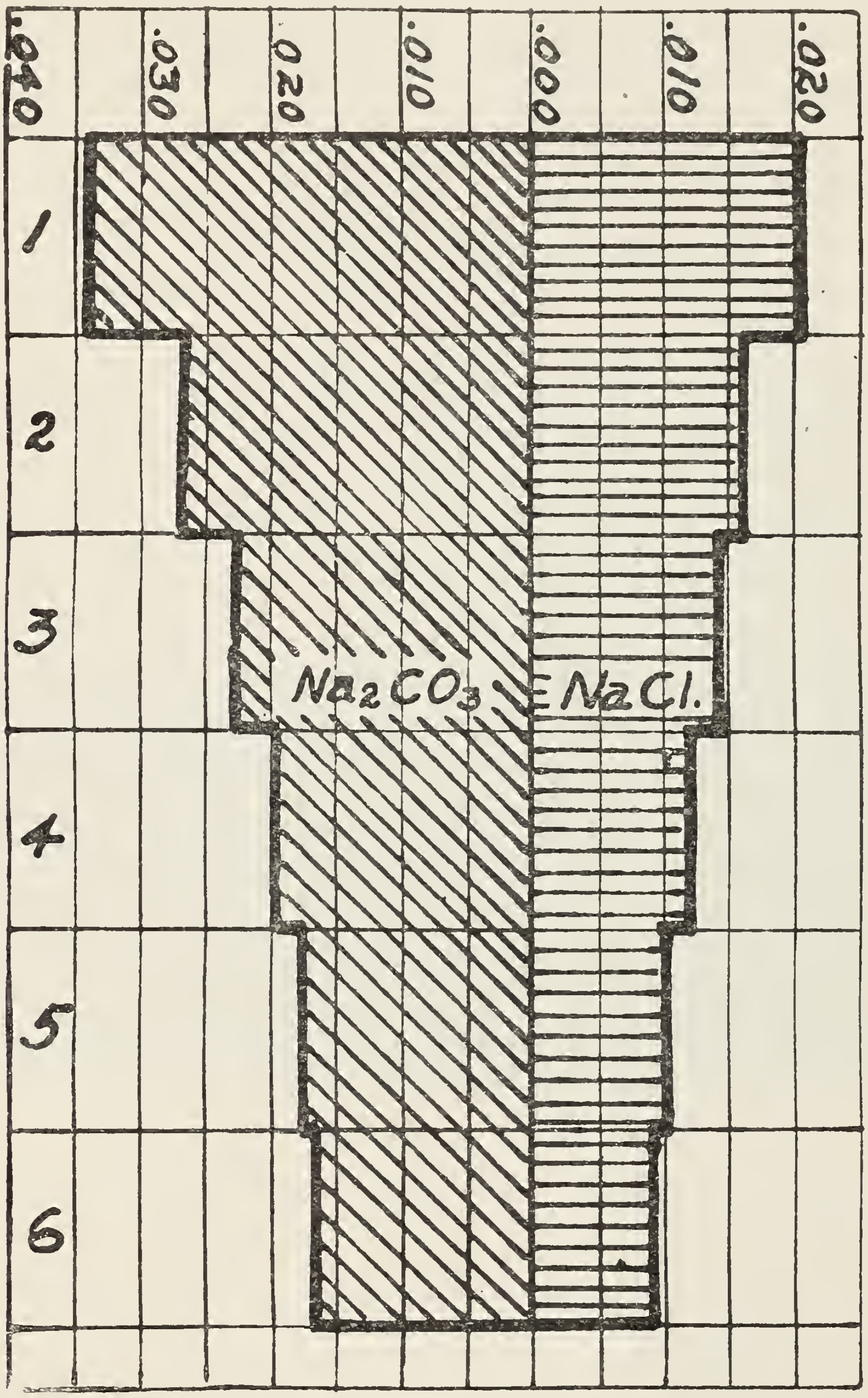

Fig. 9.—Distribution of sodium salts through a six-foot soil column in 1915.

tributed through the six-foot soil column, or partially redistributed through this column and partially removed; or as is more likely the case, together with the salts originally between the second and sixth foot, they may have been partially removed and partially redistributed below six feet.

Assuming 92 pounds to be the weight of a cubic foot of soil, there would be 320,600 tons of soil in the surface foot on 160 acres. The soil analyses show that NaCl and Na_2CO_3 to the amount of .0827 per cent, or 265.13 tons, have been removed from the surface foot in two years. The drainage water analyses show that for the same period 285.4 tons of these salts have been removed from the tract.

At frequent intervals in 1914, and each week during 1915, samples of the drainage water were taken and analyzed for alkali. An average of these samples shows that in 1914, 151.5 tons of alkali were removed in the drainage water, of which 51.6 per cent was NaCl, 34.5 per cent Na_2CO_3, and 13.9 per cent Na_2SO_4. In 1915, 183 tons of alkali were removed, of which 36.6 per cent was NaCl, 48.4 per cent Na_2CO_3, and 15 percent Na_2SO_4.

It will be noted that the water analyses made by the Division of Agricultural Chemistry, University of California, show the removal of considerable Na_2SO_4, but the soil analyses made by the Division of Soil Chemistry and Bacteriology, University of California, do not indicate the presence of appreciable amounts in the soil. This is due to the method of analysis used by the Division of Soil Chemistry and Bacteriology, as no quantitative analyses were made for Na_2SO_4 unless a qualitative analysis gave a sulphate reaction.

It is interesting to note that water samples taken on the same dates in 1915 from the Houghton Canal and from a pumping plant about two miles distant on the Kearney Park Experiment Station tract, show an average alkali content as follows:

1. Kearney Vineyard experimental drain .... 301.88 parts per million
2. Houghton Canal 33.43
3. Kearney Park Experimental Station 98.82

These figures would indicate that no great amount of alkali was added to the tract through the water used in flooding, and also that considerable more was removed in the drainage water than is found in the usual ground water.

The average alkali content for the tract has been materially reduced, as found after the 1915 tests, and is now much less than is usually considered detrimental to crops. Alkali tests made on areas where the 1916 crops were not satisfactory indicate that the alkali is not wholly responsible. There seems to be little doubt but that the physical condition of the soil is very poor in these spots and investigations are now under way to determine, if possible, a remedy for this condition.

OPERATIONS DURING 1916

During December, 1915, the west half of the tract was sown to oats. Owing to weather conditions it was not possible to plant the remainder of the tract until February, 1916, which was then sown to barley.

During the early part of April it became necessary to irrigate the barley planted on the east eighty acres. This operation took about one week and no more water was added until late in the season, this being done to facilitate the preparation of the land for alfalfa.

In 1916 one hundred and eighty tons of hay were obtained from the tract, an average of almost 1.2 tons per acre.

Fig. 10.—Barley hay on east half of drained tract, May, 1916.

SUMMARY

The tract of land chosen for this experiment was formerly a profitable vineyard, but because of a rising water table and the accompanying accumulation of alkali, passed from a vineyard through the stages of decline of an alfalfa and grain field to a poor pasture of foxtail and alkali weed. For two or three years previous to 1913 no crops were grown.

Preliminary investigations indicated the presence of alkali in dangerous quantities over a considerable portion of the tract. At certain times of the year the water table was less than two feet from the

surface and during most of the growing season was dangerously high.

The installation of the drainage system in 1913 was the first step toward reclamation. Shortly after operations were started in 1914, several errors in design were discovered, the principal ones being a too small and poorly-designed pumping equipment and too small carrying capacity of the main drain. These have been remedied. Aside from these changes made during the spring and summer of 1914, it became apparent that fewer and less expensive silt wells would have served the purpose and the canal crossings could have been omitted entirely.

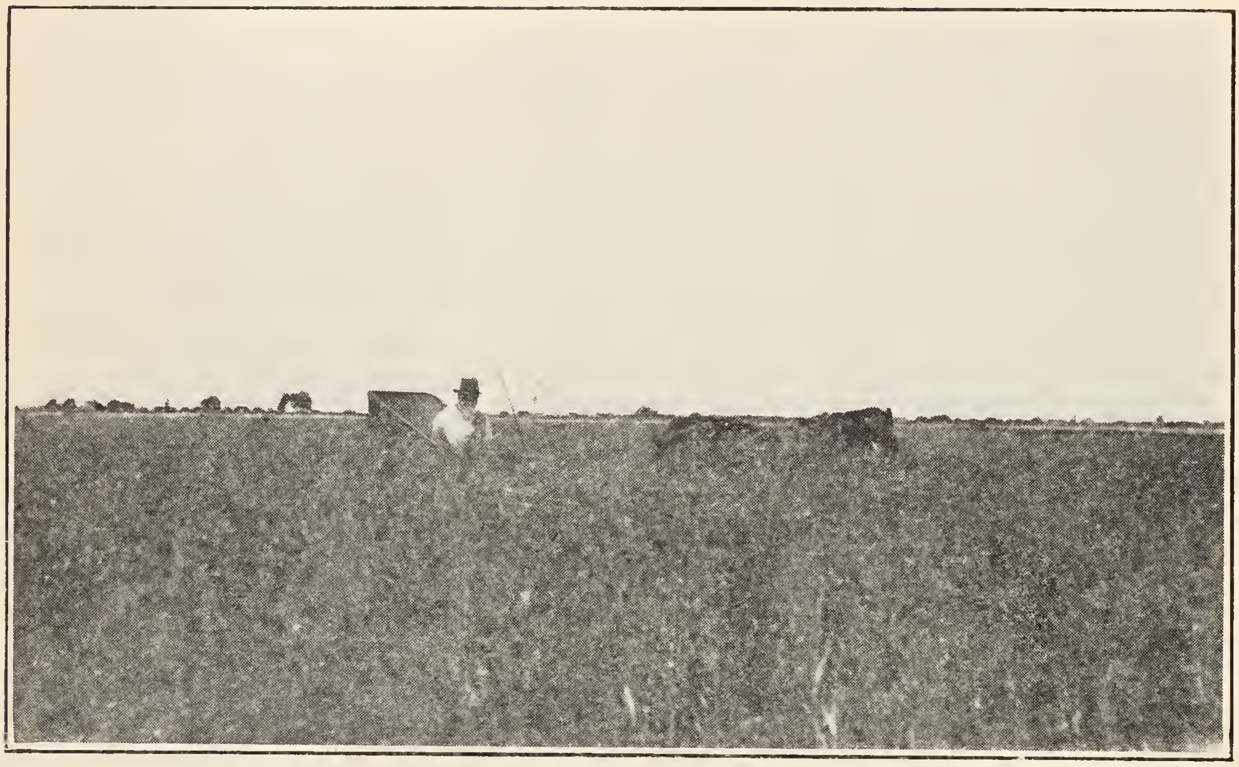

Fig. 11.—Oat hay on west half of drained tract, May, 1916.

The reclamation of this tract has involved the expenditure of $100 per acre, which is a large expense, but it must be remembered that the entire expenses incidental to putting this land into an irrigable condition and the eradication of Bermuda grass, amounting to approximately $20 per acre, would have been necessary under any circumstances and cannot be properly chargeable to drainage; in many cases of reclamation it will not be necessary. The duplicate expenses for pump and tile can be eliminated from future undertakings of this character, and this, together with changes in design that will favor economy in construction, will reduce the first cost by an additional $20 per acre, making a total possible reduction of about $40 per acre.

From measurements taken of the pump discharge, it is evident that drainage systems under similar conditions should be designed

to remove at least one cubic foot per second for each 100 acres, especially where the drained tract is entirely surrounded by undrained land.

Indications are that the lateral drains might have been placed 400 feet apart. It would have been better had the lateral tile lines been placed six and one-half or seven feet deep, instead of five and three-quarters feet. The hardpan, which was known to exist, has not proved to be a material hindrance to the movement of water.

Two years' flooding has been sufficient to reduce the alkali present to an amount which is considered safe for crops. The tests show that although there was originally nearly two and one-half times as much NaCl as Na_2CO_3 in the surface foot of soil, that this salt is much more easily removed by flooding than the Na_2CO_3, and although the latter has been reduced by 15 per cent there was, at the end of the second year, more than one and one-half times as much Na_2CO_3 as NaCl in the surface foot of soil.

There is very little doubt that cultivation and irrigation will cause the alkaline and physical conditions to change for the better much beyond their present state.

The tract has been changed, after three years, from that previously described to one producing a crop of 180 tons of grain hay in 1916, and the land is believed to be in such a condition that alfalfa can be successfully grown in 1917.

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